

# Micro-Scale Gallium Nitride Pressure Sensors for Advanced Harsh Environment Space Technology

Completed Technology Project (2013 - 2017)



## Project Introduction

The goal of this research is to study the high-temperature response of the 2-dimensional electron gas (2DEG) that occurs at the interface of aluminum gallium nitride (AlGa<sub>N</sub>) and gallium nitride (Ga<sub>N</sub>) upon mechanical deformation. These studies will enable a new platform for sensing mechanical strains (e.g. pressure) within extreme harsh environments. Sensing within hostile environments will further the understanding of space environments and advance space technology. The proposed work will contribute to investigations of planetary atmospheric profiles like that of Venus, to analyzing the material properties of aircraft structures when in hypersonic flight, and to allow sensing within rocket propulsion systems. Additionally, the use of Ga<sub>N</sub> as the material platform for sensor development can reduce spacecraft payloads by eliminating the addition of complex packaging because Ga<sub>N</sub> is temperature tolerant, chemically resistant and radiation hardened. This research supports NASAs technical research areas such as TA12 (materials that can survive the space environment and lightweight structures with reduced packaging) and TA10 (Sensors, electronic and devices, miniature instruments) as described in the Space Technology Roadmap (STR). Currently, most commercial sensors are made from silicon because it allows simple integration into integrated circuits (ICs) and their fabrication process. However, silicon cannot be used for sensors within harsh environments, which can include high temperatures, abrasive chemicals, large radiation exposure, and/or high accelerations. The electrical properties of silicon degrade at temperatures above 150°C due to the generation of thermal carriers. Interest in wide bandgap materials is thus of interest for sensing within high temperature and other hostile environments. One promising material for these applications is gallium nitride (Ga<sub>N</sub>) with a bandgap of 3.4 eV compared to that of Silicon at 1.12 eV, which enable operation of devices at temperatures greater than 600°C. Additionally, Ga<sub>N</sub> is radiation hardened, chemically inert, and mechanically stable due to strong interatomic bonding, 8.92 eV/atom compared to 2.34 eV/atom for silicon. Ga<sub>N</sub> is a promising material for the design of a platform for harsh environment sensing because, in addition to the ability to operate in hostile environments, Ga<sub>N</sub> is highly piezoelectric. When AlGa<sub>N</sub> and Ga<sub>N</sub> are interfaced, a phenomenon known as the 2DEG effect occurs. AlGa<sub>N</sub> and Ga<sub>N</sub> are both Wurtzite crystals, but their crystal lattice dimensions vary, which generate different spontaneous polarization within the materials; upon stacking these two materials, their lattice mismatch creates a positive fixed charge at the interface. The positive charge then attracts mobile electrons to the interface, creating what is known as a 2DEG layer. This work will leverage the 2DEG effect that occurs in AlGa<sub>N</sub>/Ga<sub>N</sub> heterostructure to design sensors that are electrically sensitive to mechanical strain within the device. This work will focus on the design and microfabrication of pressure sensors that utilize the change in polarization at the interface of AlGa<sub>N</sub>/Ga<sub>N</sub> when subjected to strain. However, this research will also lay the ground work for other harsh environment physical sensors like accelerometers, gyroscopes, skin friction and strain sensors. Finally, this work will attempt to characterize and model



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## Table of Contents

Project Introduction	1
Anticipated Benefits	2
Primary U.S. Work Locations and Key Partners	2
Organizational Responsibility	2
Project Management	2
Project Website:	3
Technology Maturity (TRL)	3
Technology Areas	3
Target Destination	3

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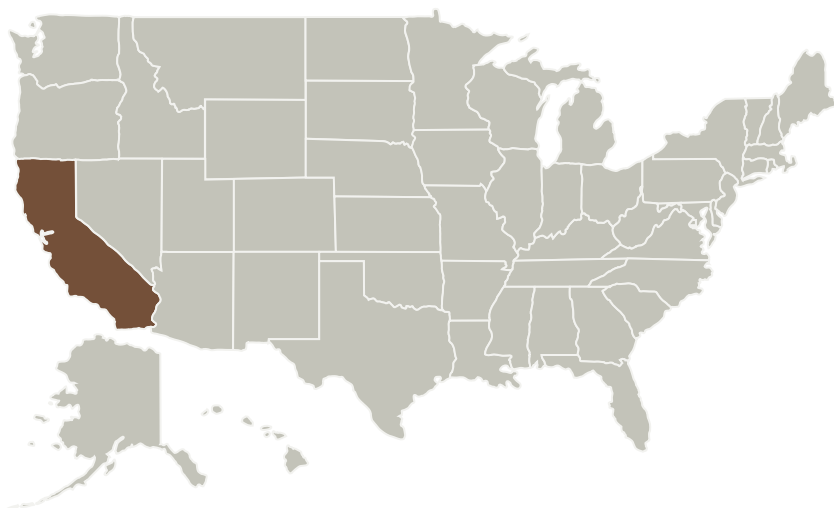


the properties of the 2DEG layer at the interface of AlGaIn and GaN to better understand this unique phenomenon in order to optimize sensors design.

## Anticipated Benefits

The proposed work will contribute to investigations of planetary atmospheric profiles like that of Venus, to analyzing the material properties of aircraft structures when in hypersonic flight, and to allow sensing within rocket propulsion systems. Additionally, the use of GaN as the material platform for sensor development can reduce spacecraft payloads by eliminating the addition of complex packaging because GaN is temperature tolerant, chemically resistant and radiation hardened.

## Primary U.S. Work Locations and Key Partners



Organizations Performing Work	Role	Type	Location
Stanford University(Stanford)	Lead Organization	Academia	Stanford, California

### Primary U.S. Work Locations

California

## Organizational Responsibility

### Responsible Mission Directorate:

Space Technology Mission Directorate (STMD)

### Lead Organization:

Stanford University (Stanford)

### Responsible Program:

Space Technology Research Grants

## Project Management

### Program Director:

Claudia M Meyer

### Program Manager:

Hung D Nguyen

### Principal Investigator:

Debbie Senesky

### Co-Investigator:

Caitlin A Chapin

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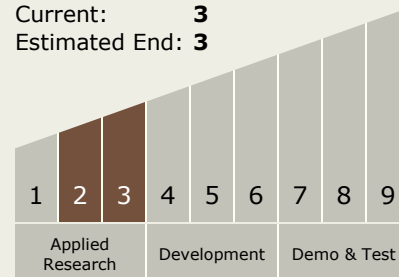


## Project Website:

<https://www.nasa.gov/directorates/spacetech/home/index.html>

## Technology Maturity (TRL)

Start: **2**  
Current: **3**  
Estimated End: **3**



## Technology Areas

### Primary:

- TX08 Sensors and Instruments
  - └ TX08.3 In-Situ Instruments and Sensors
    - └ TX08.3.6 Extreme Environments Related to Critical System Health Management

## Target Destination

Others Inside the Solar System